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The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

Groundwater

Investigating indicators for deeper circulating groundwater in the Main Karoo Basin

A completed Water Research Commission (WRC) study aimed to increase knowledge of deeper circulating groundwater in the Main Karoo Basin with the eye on future hydraulic fracturing in the area.

Background

Numerous environmental concerns have been raised with the possible exploration and development of shale gas in the Karoo. One such concern is that deep borehole drilling and the hydraulic fracturing process may create conduits through which deep-seated groundwater could migrate to shallow aquifers.

If this deep groundwater is of poor quality, and if shale gas development does facilitate upward migration of deep waters, then it is possible that poor-quality deep groundwater may blend with shallow Karoo groundwater that could be used for water supplies.

In some areas, the deep groundwater may even issue at the surface via leaking shale gas boreholes should they lose their integrity. This upward flow to the surface or near-surface will only take place for an extended period of time if the deepseated Karoo shales are sufficiently permeable to allow for groundwater flow, under sufficient pressure for the flow to rise to the near-surface, and hydraulically linked to an extensive area so that the flow continues over time (i.e. not a closed "reservoir").

Should these conditions for upward flow be present in parts of the Karoo, then this is a concern if the deep-seated groundwaters are poor quality. This concern, however, is primarily a long-term one.

The integrity of deep boreholes may be compromised decades or centuries after abandonment through the slow deterioration of the sealing cements used in borehole grouting and plugging. Likewise, the high-pressure fracking process may marginally open existing fractures that were previously impermeable and thus allow for the very slow upward migration of deep-seated groundwaters. Or crustal instability may only occur in years to come with the required intensity to cause upward movement of water through old or new faults and fractures.

The short-term value of knowing the quality of deep groundwater is that it will help in planning how to deal with the produced water that flows from the deep boreholes during gas extraction. If this water is not suitable for re-use in the fracking process, it needs to be treated to acceptable standards prior to disposal.

These short- and long-term concerns are however minor issues if deep-seated Karoo groundwaters are not poor quality. This project aimed to address this lack of knowledge by characterising the nature of the deeper Karoo groundwaters.

At present, however, this task is problematic as there are no suitable boreholes for sampling the deep formations targeted for shale gas development. The existence of warm springs in the Karoo is the closest approximation that is available through which one can obtain an idea of the nature of deep groundwater, and for this reason, these springs are the main sources of information in this project.

Two deep boreholes were also located from which samples were collected, but in both cases it is not known if the water came from the shales or deeper, underlying formations.

Method

Eight study locations were identified that span the central and south-western areas of the Main Karoo Basin, and in each of these areas "deep" samples were collected from warm springs, deep boreholes or boreholes that had previously been suspected of containing deep groundwater. Near each of these sites, a "shallow" counterpart sample was collected from boreholes for comparative purposes. From the initial 34 sites that were investigated, 20 sites were finally selected for detailed analyses.

The data and interpretations presented suggest that for the Main Karoo Basin it is possible to define a "deep" or warm groundwater, which is distinct from a shallow or cold groundwater.

Deep and shallow groundwaters were defined as follows:

a) Deep Groundwater
- "Y" shaped Stiff diagram
- Low ^{14}C value
- Temperature > 25°C (but not always the case)

b) Shallow Groundwater
- Hexagonal shaped Stiff diagram
- High ^{14}C value
- Cold temperature < 25°C

The deep groundwater were further characterised as:
- An anaerobic NaCl water type that may be warm (>25°C) but does not have to be.
- An older water characterised by low tritium and ^{14}C and by low $^{36}Cl/Cl$ and $^{3}He/^{4}He$ ratios.
- Very low nitrate as a result of denitrification.
- Low magnesium, probably due to ion exchange reactions with the aquifer matrix.
- Lower δ18O and δ2 H than those in shallow groundwater.
- Low alkalinity possibly due to precipitation of $CaCO_3$ at higher pH.
- Low uranium and vanadium (and maybe other metals) as a result of anoxic conditions.
- Very low radon and radium as a result of low uranium concentrations in deep groundwater.
- Relatively high fluoride, possibly as a result of long-term dissolution of fluorite and concomitant partial removal of calcium.
- Relatively high methane and helium gas concentrations.
- Relatively high boron levels.

Table 1. Indicators of deep flow

Determinand	Deep groundwater criteria	Units
^{14}C	<60	pmC
$\delta^{18}O$	<-6	‰ SMOW
F^-	>3	mg/L
$\%Na^+$	>70	%
Mg^{2+}	<10	mg/L
U	<0.05	µg/L
Alkalinity	<100	mg/L HCO_3^-
B	>300	µg/L
V	<1	µg/L
Li	>100	µg/L
$\delta^{11}B$	<+30	‰
NO_3^-	<1	mg NO_3/L
$^{36}Cl/Cl$	<100	10^{-15}
Rn	<10	Bq/L
H_2S	>1	µcc/kg
^{3}H	<1	TU
Na^+	>300	mg/L
pH	>9	
^{4}He	>30000	µcc/kg
$^{3}He/^{4}He$	<0.1	R/R_0
Temperature	>25	°C
CH_4	>10	cc/L

Conclusion

This study set out to identify indicators of deep groundwater flow in the Main Karoo Basin. It was not possible to obtain groundwater samples from the deep-seated shales that are being considered for shale gas exploration and development because no suitable deep boreholes exist.

Instead, samples from warm springs and two deep boreholes that pass through the shales were obtained as the best approximation of deep-seated groundwaters in the Karoo at this stage.

Deep and shallow groundwaters were characterised and determinands were identified to differentiate these waters. A provisional guide on the limits for these determinands was provided (Table 1), and at this stage, this list can be used as guidance on differentiating deep form shallow waters.

The determinands that appear to be most reliable in identifying deep groundwater were grouped and prioritised for future monitoring programmes.

While this project noted fairly consistent geochemical patterns throughout the vast area of the Karoo, it must be stressed that the analyses, conclusions and recommendations presented pertain to a relatively small sample number of water and gas samples derived from sources of unknown depths.

Further reading:
To order the report, *The use of chemistry, isotopes and gases as indicators of deeper circulating groundwater in the Main Karoo Basin* (**Report No. 2254/1/15**) contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.